LOS ANGELES: SCHOOL OF ENGINEERING AND APPLIED SCIENCE

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TO: G. Quittschreiber

FROM: Ivan Catton

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SUBJECT: Technology Meeting with Zion and Indian Point Utilities on Core Melt Accident Sequences for Zion/Indian Point, 7-8 May 1980

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUMMARY

The two day meeting was to yield an exchange of information between the utilities and the NRC staff without addressing licensing issues. The utilities demonstrated an apparent lack of initiative by not presenting any of their own work. It appeared as if the utilities were waiting for the NRC staff and consultants to resolve issues and questions for them. The position taken by the utilities is that their plants, Z/IP, are better than the WASH-1400 typical PWR and that they do not need to do anything to mitigate consequences of class 9 accidents. This is to be contrasted with the view of the staff that one must look at the back end of the various accident sequences to make significant reductions in risk because of the large number of contributors, e.g. one must look to mitigation devices. The IREP program has not focused on Z/IP as yet and in this respect seems to be unresponsive to NRR needs.

The most important technical issue is the MARCH/CORRAL predicted containment pressure spike. The calculated rate of rise of pressure leads to unreasonable design requirements being placed on mitigation devices and its magnitude without them to containment failure. The modeling leading to the pressure spike prediction deserves a great deal more attention. At present no credit is given to the ability of sprays to condense steam nor to the possibility of sprays quenching a hydrogen burn. Emergency power to the spray system, appropriate spray location and flow characteristics may be sufficient to eliminate the pressure spike and requlting requirements for venting of the containment. The utilities and their consultants concluded that some progress was made in reaching a common ground regarding knowledge of assumptions made in the various analyses. They felt that the steam spike is still a major uncertainty. Hence the utilities don't believe that it is clear whether one wants a dry or wet containment. The heat source for the steam is molten core material and quantifying it was noted to require a more realistic core slump and melting analysis (one shouldn't have to deal with the whole core). Further, more attention to the dynamics of the reactor cavity itself is needed.

The staff noted that they needed answers in months--not years and that they may have to redirect ARSR programs. Answers to questions about debris bed coolability, steam pressure spikes, steam explosion induced steam generation tube failure and hydrogen burning were considered to be primary. The debris bed coolability question leads directly to answering questions about the need for a core catcher. The staff felt that they had to determine how they would arrive at a design basis for mitigation features.

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GENERAL DISCUSSION

Selection of Representative and Enveloping Sequences. Dr. DiSalvo, NRC staff, stated that the WASH-1400 philosophy would be adhered to. Their procedure would be as follows:

1. Decide what risk reduction should be required. One order of magnitude has been tentatively selected.
2. Select accident sequences.
3. Calculate the accident environment.
4. Determine the mitigation system functional requirements.
5. Design the mitigation system to meet the requirements.
6. Calculate the net effect on risk.

The accident sequence was stated to be important because it determines the physical phenomena that will present challenges to the system. Its not clear that this is the case. It seems to me that many characteristics of the accident sequence leading to risk are similar and one only needs to know whether power and water are available and where. DiSalvo believes that one must look at the back end of a sequence to make significant reductions in risk because of the large number of contributors. This means mitigation devices.

Check valve failure and small breaks were seen to dominate as initiators of a sequence. System major contributors are electric power, auxiliary feed water, power conversion and containment spray. Physical phenomena resulting that lead to radioactive release were over pressurization (from steam), hydrogen burn and steam explosions.* The dominant sequences leading to containment failure are typically

a) small break or some transient as an initiator
b) human error compounding the problem
c) hydrogen burn
d) containment safety features unavailable
e) containment failure above ground.

The utility view in this area was given by Dr. D. Walker. He said that the design goal was to do better than the WASH-1400 typical PWR and that it has been demonstrated that Z/IP are already better. Therefore, no further effort is justified. He further noted that the staff placement of the WASH-1400 PWR at the Z/Ip sites is not the proper approach. Plant specific features, such as those of Z/IP, must be incorporated into the study. Apparently a number of special features were incorporated into Z/IP to accommodate the high population density during the licensing stage. George Klupp, a utility engineer, expressed concern that interesting low probability sequences might dominate just because they are interesting (an uninteresting sequence is one where nothing happens). A further consideration, as expressed by D. Glazer of W, is increased operator actions and possible blunders.

*NOTE: It is possible that sprays could eliminate the first two as a threat and steam explosions are not considered as dangerous as assumed in WASH-1400.

Evolution to Meltdown. Dr. J. Rivard of SANDIA gave his view of how an accident evolves to a meltdown and what the uncertainties in our understanding are. The process is a complicated, not well understood heat transfer problem. He noted that the areas of uncertainty were

Early in the sequence	Late in the sequence
clad failure	crusting
fission product distribution	steam explosion
early melting	melt-water interactions
internal structure failure modes	debris coolability
blockage effects	vessel failure mode and timing
melt motion	

The picture presented was one of a hundred year research program. It is not clear how well one has to tie down the uncertainties before coming to conclusions. It is clear that NRR cannot wait for RSR to address the above uncertainties before making decisions regarding the need for mitigation devices. It is my opinion that we will not be able to improve our knowledge sufficiently in the near future to do any good. One should, however, be able to identify the sensitivity of the uncertainties to risk and bound them enabling the decision making process to procede.

MARCH Code. The MARCH code developed at BCL plays an important part in studies of class 9 accidents. With it, the infamous pressure spike is predicted. Dr. P. Cybulkis gave an overview of the modeling, assumptions and limitations of the MARCH code. The code is made up of components each dealing with part of the sequence. They are

Meltdown-BOIL code

Assumes fuel melts, moves, refreezes according to one of the following models

a) melt runs down, refreezes then melts again to maximize downward penetration. Melt does not dribble into lower plenum until core support plate fails.

b) high upward heat transfer to maximize upward penetration (not sure of details of the model).

c) as soon as a node melts it falls into the lower plenum.

The models contain a great deal of uncertainty and which is most likely is not known. Dr. Cybulkis believes, as do I, that model 'a' is most likely.

Vessel Failure-HEAD code

Evaporates the water in the lower plenum, heats up the head and then melts it. A number of calculations lead one to believe that water will be in the head when the core support plate fails with some degree of certainty.

Entry of Molten Debris into the Reactor Cavity-HOTDROP code

When the vessel fails, the fuel pool is assumed to fragment into some assumed radius particles and to transfer energy to water with an assumed heat transfer coefficient. This gives the steam spike. The water can be the result of accumulator dumping or it can be in the cavity before vessel failure.

Concrete-Corium Interaction-INTER code

A code written at SANDIA to account for the complex chemical reactions and heat transfer taking place when hot corium decomposes concrete. An assumed heat transfer coefficient couples the two materials. The amount of concrete penetration and gas production are predicted. The code is only valid during the very early stages when the corium pool is very hot. It is not clear what is done past the first several hours.

Containment Thermal Hydraulics-MACE code

The MACE code is a quasi-steady multi-compartment model with no inertial terms in the momentum equation. It receives as input the amount of steam generated as well as gases resulting from decomposed concrete.

Some uncertainty studies have been carried out and others are currently underway. If the uncertainty of interest is fission product release then the key parameters are fission product plate out, fission product source term, and containment failure modes. Little direct dependence on the core melt models was found. This conclusion bears on Dr. Rivard's concerns. Uncertainty in containment pressure depends on how the molten pool enters the reactor cavity and the timing of the accumulators. Whether there is water in the lower plenum or not did not appear to be too important. In coming to conclusions based on these uncertainty studies, one must not loose sight of the primitive modeling that is the backbone of the MARCH package.

The pressure spike calculated to occur immediately following failure of the vessel results from release of primary system high pressure steam (1/5) and interaction of the molten materials with accumulator water (4/5). Another sequence might have resulted in lower primary system pressure and accumulator actuation before vessel failure. Evaporation would take place slowly and the pressure spike would not occur. The slow pressure rise allows mitigation measures to be taken. An ADS would allow operator action to accomplish this.

In-Vessel Debris Bed Cooling. Dr. Lipinski of SANDIA presented the results of his calculations showing that dryout could occur. He assumed that the entire core melted and as a result was faced with very deep beds. The fragmentation process leading to particle sizes that must be dealt with is not well understood. Differences of opinion between Dr. R. Henry, (now with Fauske and Associates) a consultant to the utilities, as to the expected particle sizes were large.

Henry refers to French work resulting in sizes on the order of centimeters whereas Lipinski refers to SANDIA work resulting in sizes on the order of fractions of a millimeter. The latter result in dryout and remelting.

Mechanism for Introducing Water into the Vessel for Various Sequences. It was noted that HPI, LPI and a number of non-ECCS sources such as seal water were available for introducing water into the vessel. Further all ESF operate off diesels (with few exceptions). The question will become one of operator action.

Progression of the Radiological Source Term. Radiological materials that result in risk are in the water, vapor phase and core debris and they can plate out on various surfaces. Most are found in the water. Fission products had to penetrate subcooled water in the pressurizer at TMI-2 to get out. This says that plate out is not too important and that water is the important transport path.

MARCH Prediction of Ex-Vessel Sequence--The Pressure Spike. The most important aspect of the results is the pressure spike. The initial rapid rise at vessel failure is followed by a pressure decrease due to condensation. This is followed by a slow rise as the structure heats up and becomes less effective as a heat sink. The second peak is as high for some sequences as the first. Without some means of cooling or venting, containment failure will occur. No credit was given for containment cooling or sprays. The possible quenching of a hydrogen burn by sprays has not been considered. Zion has diesel power to the sprays whereas Indian Point does not.

Heat transfer from the particles (and their characteristics) to the water are key factors in determining the pressure spike. The dynamics of the process are also important. For example how can enough steam be generated in such a short period of time to pressurize the entire containment without blowing the water away. The small particles necessary to get such rapid heat transfer result from a steam explosion that will probably blow the water out of the cavity. A rapid pressure rise does not allow coolers to be effective (sprays could attenuate it). The present calculations require 10×10^6 ft^3/min vent rate whereas a five minute pressure rise only requires a 350000 ft^3/min vent rate. This area deserves a great deal more attention. It does not appear to be a part of the RSR class 9 program.

Water in the Reactor Cavity. At present water that gets into the cavity is by accident. A curb between the sump and the cavity in one of the plants will limit the water to that from the sprays. It was estimated by the utilities that about 25,000 gallons will be in the cavity before vessel failure. More would be in the cavity if the curbs w re drilled. In that Indian Point loses the sprays on loss of power, it is not clear where the 25,000 gallons come from. Water in the cavity helps with cooling and decreases the potential for penetration of the base mat but feeds the pressure spike. On the basis of the MARCH calculations, the utility position is one of reluctance to deliberately flood the cavity.

Ex-Vessel Debris Bed Coolability. The SANDIA view is that even with a water supply one cannot guarantee debris bed coolability when the entire core melts and is in a pile underneath the vessel. It is not clear that the total core will melt and if it does it will probably spread. A need to guarantee a water supply to the cavity seems to be appropriate.

Lipinski (SANDIA) has extended his work to deep beds where the simple Darcy law approach is not valid. He has not, however, fully accounted for particle size distribution in that he weights fines too heavily. This aspect with the piling up of the debris may be too conservative. As noted by Henry, small particles are the result of a steam explosion that spreads the bed. The deep bed and fines are therefore too conservative. I agree with this view. It is not clear, however, that Henry's conclusion (the utility position) that dryout will not occur and that a retention device is not needed is correct. SANDIA fragmentation studies will be very important in answering some of these questions.

Steam Explosions. A quote of a statement by DiSalvo seems to sum up the steam explosion area--"Best available information indicates that failure due to a steam explosion induced missile is much less probable than previously assumed to be--if not impossible". Steam explosion sequences are probably not as important as they once were and it is time to re-direct our resources. There are still questions about the effect of molten material-water interaction effects on rapid heat transfer and fission product purging.